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SENSECAM V2.3B USER GUIDE

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1. Introduction

1.1. Overview of v2 SenseCam

SenseCam is a small digital camera that is designed to take photographs automatically without user intervention. Unlike a regular digital camera or a cameraphone, it does not have a view finder or a display that can be used to frame photos. Instead, it is fitted with a wide-angle (fish-eye) lens that maximises its field-of-view. This in turn means that nearly everything in front of the camera is captured. In addition to the camera functionality, a number of different sensors are built into the v2 SenseCam. These include a light intensity and colour sensor, a passive infrared (body heat) detector, a temperature sensor and a tri-axis accelerometer. These sensors are monitored by the camera's microcontroller, and changes in sensor readings can be used to automatically trigger the camera shutter. For example, a significant change in light level, or the detection of body heat in front of the camera can be used as triggers. Additionally, an internal timer may be used to trigger the shutter, for example causing an image to be captured automatically every 30 seconds. The maximum possible rate is an average of around one photo every 5 seconds, i.e. 12 photos per minute. SenseCam also has a manual trigger button that lets the wearer take pictures in the more traditional fashion, albeit without the use of a viewfinder.

The VGA resolution images are stored as compressed .JPG files on an internal flash memory card (currently 1Gbyte cards are fitted). The typical image size (around 30k bytes) allows for over 30 thousand images to be stored in the camera. In addition to image data, the memory card is used to store a log file, which records the sensor data each time the sensors are read (every few seconds). The log file also records the reason for taking each photograph (e.g. manual shutter press, timed capture or significant change in sensor readings). The log file is in a comma-separated value format suitable for importing directly into Microsoft Excel[1] and many other data manipulation tools. The SenseCam has a built-in real time clock that ensures the timestamps of all files on the storage card are accurate. Timestamp information is also recorded in the log file along with each entry.

[1] Note that Excel 2003 has a 32k row limit which can be exceeded by large sensor files.

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Figure 1: Example images captured by SenseCam.

In trials to date, users have worn the camera on a cord around their neck, although it would be possible to use a clip for pockets or belts. One advantage of using a neck-cord to wear the camera is that it is reasonably stable when being worn, and it is also reasonably high-up (closer to the wearer's eyeline) which generates more compelling images. The camera contains a rechargeable lithium-ion battery that lets it run for a complete day on a full charge. It takes around three hours to recharge using a mains power adaptor or a PC USB connection. There is an on-off button on the camera, which can be used to save the battery and prevent any sensor data logging/photograph capture. LEDs and an internal sounder are used to give the wearer feedback.

The high speed USB interface used for recharging is also used to transfer the image and sensor data to a PC. An expansion connector on the bottom of the camera may potentially be used to connect a number of different add-on devices, such as an external battery, an additional camera, wireless communications or additional sensors. The expansion connector can also be used to update the firmware that controls the operation of the SenseCam, for example to add new features or integrate add-on devices. A future enhancement will include a microphone and audio recording and audio-level triggering circuitry (so that photos can be taken automatically in response to noises).

1.2. This document

This document is a user guide for the v2.3b SenseCam. It describes the operation of the camera and of the associated PC software that is used to display SenseCam image data. It also describes in some detail various options available to the user of a SenseCam to alter the default configuration of the unit using a PC and a USB cable. Unless specifically stated, the descriptions herein are based on the most recent firmware build.

For a very quick overview of the v2.3b SenseCam and its operation, please refer to the quick-start guide in Section 2.

1.3. Microsoft Limited Licence Agreement

Please note the terms and conditions of the Microsoft Limited Licence Agreement associated with the use of the SenseCam hardware and software. This agreement has to be signed by all SenseCam recipients external to Microsoft before they are supplied with the SenseCam hardware and MSRC Viewer/Importer Software.

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2. SenseCam quick-start guide

2.1. Turning the camera on and off

The SenseCam is turned on and off using the small round button on the top of the unit. A rising tones indicates that the camera is switching on and a falling tone indicates that the camera is switching off. The power button must be pressed for several seconds before the camera will respond and you will hear the tone.

The SenseCam takes several seconds to power up, during which time the yellow light will be on. When ready for use, the SenseCam will beep and the green power light will come on instead.

If battery charge is very low, the SenseCam will not switch on when the power button is pressed, but will make a low-pitched buzzing/warbling sound instead. If this happens the camera must be charged up.

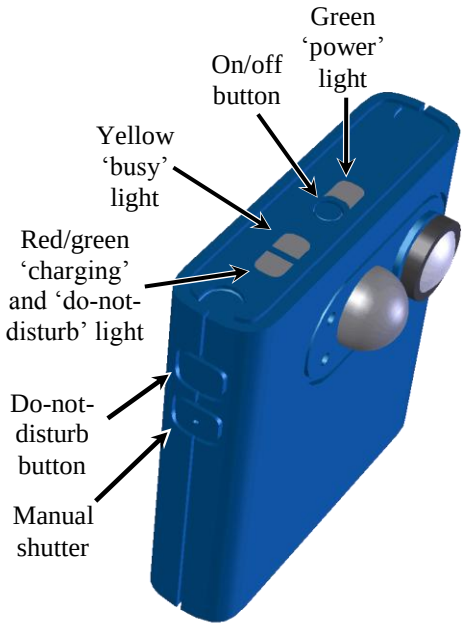

Figure 2: SenseCam lights and buttons

2.2. In use

During operation, the yellow light will blink whenever the SenseCam is busy recording a photograph or sensor data. The green power light will be on continuously if the battery has plenty of charge and it will blink occasionally if the battery is getting low.

In order to explicitly take a picture, press the manual shutter button (the bottom of the two side buttons) at any time. Note that the camera takes several seconds to save the picture, during which time further presses of the manual shutter will have no effect.

The top of the two side buttons is a do-not-disturb button which causes the SenseCam to stop taking pictures for 7 minutes. During this time, the red LED will be on. Fifteen seconds before pictures start again there will be a beep and the LED will flash. Pressing the do-not-disturb button again resets the do-not-disturb timer back to 7 minutes. Pictures can also be re-enabled using the manual shutter button.

Note that the SenseCam may be supplied with a black protective plastic cover fitted over the glass lens, to protect it from damage during shipping. This can be removed by carefully pulling it away from the body of the camera (it is a push fit and does not need to be unscrewed). In day-to-day operation the lens cover is not likely to be needed.

2.3. Charging

The battery will charge whenever the SenseCam is connected to a computer or a mains charger. *Before connecting the camera to a charger or to a computer, please make sure that the unit is switched on. If the unit will not switch on due to a flat battery (low-pitched buzzing/warbling sound), please connect it to a charger or a computer for 15 minutes, then*

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disconnect it, turn it on and reconnect as usual. When plugged in, a flashing green light indicates that the battery is charging; solid green indicates fully charged.

It takes around 3 hours to charge the battery from flat. It is not possible to 'over-charge' the battery, and it is safe to leave plugged in overnight. It is also OK to 'top up' the battery by re-charging it before it is fully exhausted. A fully-charged battery should allow up to 36 hours of operation although this varies with frequency of image capture and may be as low as 12 hours.

Connecting it to a PC or charger while it is switched off may result in the unit appearing not to respond as expected (for example, the charging light may not come on). If this happens, it is recommended that you disconnect the camera, switch it on, and then re-connect.

2.4. Transferring data

Photographs and sensor data may be transferred from the camera to a computer using the USB cable supplied. No special USB drivers are required; the camera will simply appear as an external flash drive under Windows. It is possible to browse SenseCam images (which will be recorded as a sequence of .JPG image files in various folders on the camera) directly from Windows, and to load the sensor data into Microsoft Excel. However, it is recommended to use the SenseCam Image Viewer software supplied to move the images from the SenseCam onto the PC because this software performs additional operations, such as tagging files and synchronising the SenseCam real-time clock. Transferring the images may take many minutes; a status bar indicates progress.

2.5. SenseCam Image Viewer software

One way of copying and viewing SenseCam images and sensor data is to use the SenseCam Image Viewer software supplied with the camera. This may be installed directly from the camera – simply connect it to the PC via USB, and run setup.exe from the folder within the \PCVIEWER folder. The software will also install the .NET framework 2.0 if required. During installation select 'Advanced Operation' if you want to be able to view sensor data.

Following installation, whenever the camera is subsequently connected to the PC the 'Import photos from SenseCam using SenseCam Import' option should be selected. Section 3 gives a lot more detail about the installation, use and configuration of the MSRC viewer software.

Note that currently the software requires that the user is a local administrator of the machine to run properly.

2.6. General

The SenseCam is a research prototype. Please bear in mind that it is not as robust as a typical commercial product. It is not particularly waterproof so please be careful in the rain.

Documentation is supplied on the camera itself, in the \DOCS folder.

Please note the terms and conditions of the Limited Licence Agreement associated with the use of the SenseCam hardware and software before you attempt to install or use the PC software. This agreement has to be signed by all SenseCam recipients external to Microsoft before they are supplied with the SenseCam hardware and MSRC Viewer/Importer Software.

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3. MSRC SenseCam PC viewer software

The SenseCam is supplied with PC software that has been developed by Microsoft Research Cambridge. This software comprises two main applications: (1) the SenseCam Image Importer, which can be used to transfer images and sensor data from the SenseCam to the PC; and (2) the SenseCam Image Viewer, which can be used to view previously imported data. The Image Viewer is started automatically following the import operation to allow the user to review the image and sensor data that has just been transferred.

Even if you do not intend to use the SenseCam Image Viewer, it is highly recommended that you do use the SenseCam Image Importer to transfer data from the SenseCam to the PC. If you simply move files from the SenseCam to the PC using Windows Explorer (or a similar application) you will not enjoy several benefits of using the Image Importer, such as automatic synchronisation of the SenseCam real-time clock with the PC, image tagging with EXIF data, or automatic image rotation.

Please note the terms and conditions of the Limited Licence Agreement associated with the use of the SenseCam hardware and software before you attempt to install or use the PC software.

3.1. Installing the MSRC software

The SenseCam Image Importer and Viewer software is supplied on the camera. Using Windows Explorer, browse to the '\PCVIEWER' folder on the camera's flash disk. Inside this folder there is another folder with a numeric name, such as '1.11.0'. (The numeric name indicates the version number of the SenseCam Image Importer supplied on the camera. Later versions may be available from Microsoft Research.) Inside this folder, there is an application called 'setup.exe'. Install the software by double-clicking on 'setup.exe' to run it.

The SenseCam Image Viewer requires the .NET framework 2.0; the application installer will first install the .NET framework if necessary. When this is complete, the application itself will install. Installation is most straightforward if you accept the default options; in this case you only need to click on the 'Next' button at the bottom right of each of the four installation dialog boxes.

In the second dialog box during installation there is an option to choose "Basic" or "Advanced" operation. The "Basic" option exposes all the basic features of the viewer for editing, bookmarking, and viewing the images. The "Advanced" option is a bit of a misnomer – it simply exposes a number of miscellaneous experimental functions that are not yet fully refined. This extra functionality is displayed as a toolbar at the top of the application window. (You can change this setting retrospectively if necessary, see Section 3.6.) Note that if you want to be able to view sensor data, you should select 'Advanced operation'.

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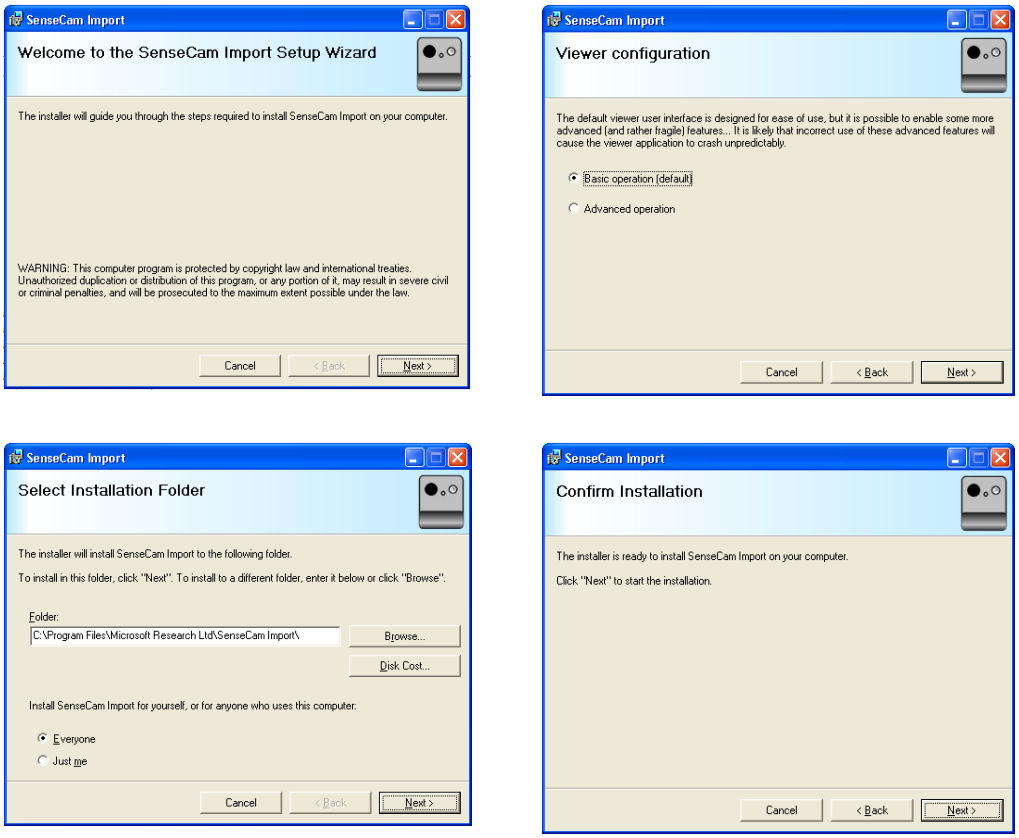
SenseCam Import
Welcome to the SenseCam Import Setup Wizard
The installer will guide you through the steps required to install SenseCam Import on your computer.
WARNING: This computer program is protected by copyright law and international treaties. Unauthorized duplication or distribution of this program, or any portion of it, may result in severe civil or criminal penalties, and will be prosecuted to the maximum extent possible under the law.
Cancel
< Back
Next >
SenseCam Import
Viewer configuration
The default viewer user interface is designed for ease of use, but it is possible to enable some more advanced (and rather fragile) features... It is likely that incorrect use of these advanced features will cause the viewer application to crash unpredictably.
Basic operation (default)
Advanced operation
Cancel
< Back
Next >
SenseCam Import
Select Installation Folder
The installer will install SenseCam Import to the following folder.
To install in this folder, click "Next". To install to a different folder, enter it below or click "Browse".
Folder:
C:\Program Files\Microsoft Research Ltd\SenseCam Import\
Browse...
Disk Cost...
Install SenseCam Import for yourself, or for anyone who uses this computer:
Everyone
Just me
Cancel
< Back
Next >
SenseCam Import
Confirm Installation
The installer is ready to install SenseCam Import on your computer.
Click "Next" to start the installation.
Cancel
< Back
Next >

Figure 3: When installing the SenseCam Image Viewer software it's easiest to use all the default options and just click the 'Next' button on each of the dialog boxes.

When the software installation is complete there will be two new icons on the desktop. The 'SenseCam Image Viewer' icon can be used to run the Image Viewer application, whilst the 'SenseCam Images' icon is a shortcut to the folder where the imported image sequences are stored. It is also possible to use the Windows Start menu instead of the desktop icons (select 'Start' then 'All Programs' then 'SenseCam' followed by 'SenseCam Image Viewer' or 'SenseCam Images').

Figure 4: After installation there will be two new desktop icons.

3.2. Using the SenseCam Image Importer

When you attach the SenseCam to a PC, Windows will bring up a dialog box asking you what you want to do with the associated files. As long as the SenseCam Image Viewer software has been installed, one of the options will be 'Import photos from SenseCam using SenseCam Import'. Select this option whenever you dock the SenseCam.

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It is possible to tell Windows to automatically use SenseCam Import *every time* a device containing images is connected to your PC (check the 'Always do the selected action' box). However, this is *not recommended* if you are likely to plug other devices with images (such as a regular digital camera) into the PC from time to time because these will also cause the SenseCam Image Importer to run which is probably not desired behaviour. Also note that an 'empty' SenseCam will not result in the SenseCam Import option being displayed.

Prior to importing the images, the SenseCam Image Importer will show a dialog requesting the user to enter a name for the set of images that are about to be imported. Though optional, specifying a name here helps to keep the SenseCam images organised. When new images are imported from the SenseCam, the SenseCam Image Importer creates a new folder on the PC's local storage to store them in. This folder is named with the time and date of import (which is not directly related to the times that the images and sensor data were collected) and the name entered by the user into the dialog prior to importing. An example folder name is "10-February-2006 10-40-43 # Visiting London". An example without the album name specified is "10-February-2006 10-40-43 #".

The date-based folder names that have been created by default can be manually edited afterwards using Windows Explorer. The viewer application assumes that folder names will start in the default way in order to sort them chronologically. It is strongly advised to avoid changing the part of the folder name before the '#' character. However, it is fine to change the folder name after the '#' character by either *appending* text after the '#' character to name the set of images or *changing* the text if a name was already specified during the importing of images. Anything after the '#' will be ignored by the viewer application.

The easiest way to change the image folder names is to use the shortcut to 'SenseCam Images' which was created on the desktop/in the Start menu when the software was installed. Selecting this shortcut starts up a new Explorer window with all the imported folders displayed. By default, the location of this is "C:\Documents and Settings\<username>\Local Settings\Application Data" folder. This location may be changed by editing the Windows registry (see Section 3.7). If you want the viewer application to use SenseCam (or other) images already stored on your machine, edit the registry string to point to the directory containing image folders or copy/move those directories into the image root directory.

3.3. Using the basic features of the SenseCam Image Viewer

When the SenseCam Import is complete, the SenseCam Image Viewer application will automatically start and load in the new images. If the SenseCam Image Viewer is started via the Windows Start menu (or via the shortcut on the desktop), it will present a list of all the folders imported to date, and whichever is selected will be displayed in the viewer.

Having loaded up a set of images, the sequence can be replayed slowly using the 'Play' button (labelled '>') or more quickly using the 'Fast Forward' button (labelled '>>'). As the sequence plays, the slider underneath the image progresses from left to right. Playback can be paused at any point with the 'Pause' button. The mouse can be used to manually drag the slider to a particular position and have playback continue from that point. It is also possible to play the image sequence in reverse using the 'Back' and 'FastBack' buttons. Any images in a sequence which are unwanted may be removed by using the 'Delete' button: this does not actually delete the files, but merely records (in a configuration file) that they are not to be used as part of the playback sequence.

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The wide-angle (or 'fish-eye') lens fitted to SenseCam introduces distortion to the image – lines which are straight in the real world will tend to be captured as curved lines. Clicking on the 'Undistort' button to the left of the 'FastBack' button puts the Image Viewer into a mode where it approximately corrects for this distortion. Clicking on the same button a second time will restore the image to the original form. A side-effect of using the undistortion option is a small black band at the top and bottom of the images.

The viewer also has to modes: Advanced Mode and Simple Mode. Advanced Mode (**Error! Reference source not found.**) reveals the editing features of the viewer such as image deletion, bookmark creation, image (un)distortion and the list of bookmarks. Simple Mode (**Error! Reference source not found.**) hides all the editing features of the viewer and simply displays the image and playback controls. Simple Mode is useful for viewing the images without the distractions and potential dangers of accidental deletion of images. Upon start-up, the viewer application starts in Advanced Mode. To enter Simple Mode, click the "Simple Mode" button located in the lower left-hand corner of the viewing pane. Once in Simple Mode, clicking the "Advanced Mode" button switches the application back to Advanced
Mode.

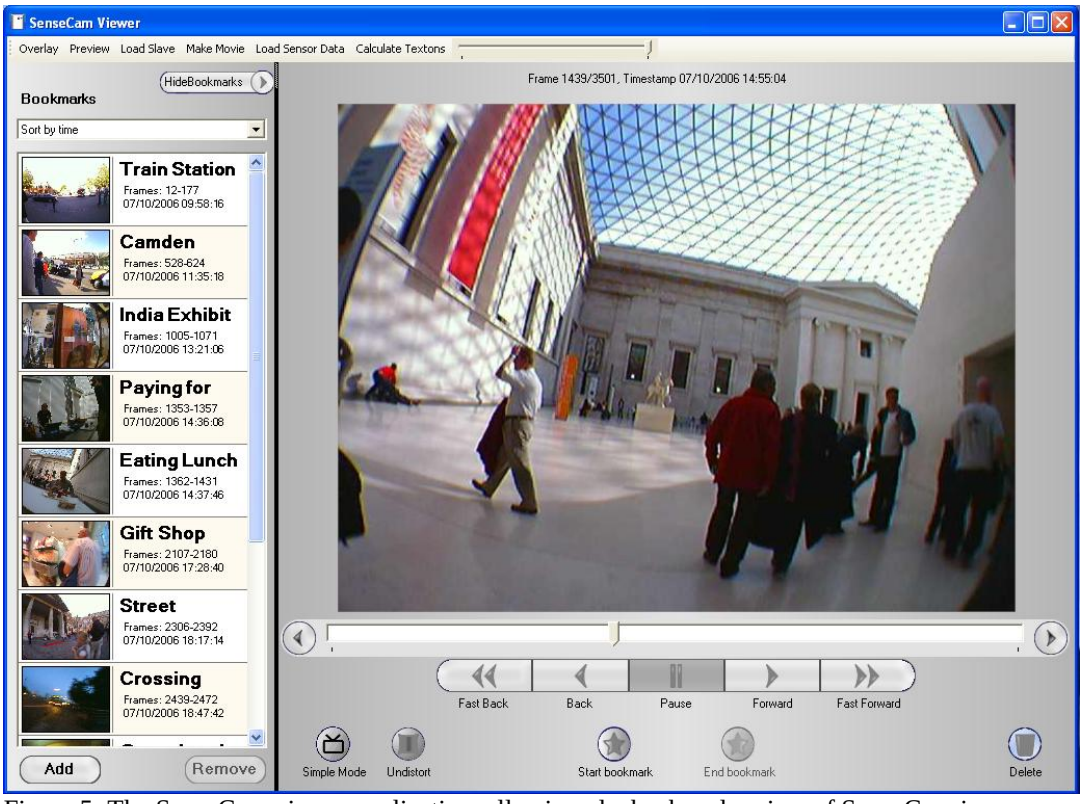

Figure 5: The SenseCam viewer application, allowing playback and review of SenseCam images.

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Figure 6: The SenseCam viewer application in Simple Mode which hides editing functions.

With long sequences of images, it can be useful to associate 'Bookmarks' with certain images. A bookmark is created by pausing playback on the image in question, and then clicking on the 'Add' button at the bottom left of the screen. The bookmark will appear as a thumbnail on the left-hand side of the display; by clicking on the default the name of '<bookmark>', a more meaningful name can be assigned. Once bookmark(s) have been created, it is possible to return to the image associated with the bookmark simply by clicking on the bookmark. The bookmark text is also shown as overlay text (**Error! Reference source not found.**) on the images in the viewer. This overlay feature can be turned off by pressing the "Hide Text" button (located in the lower-right corner) found in "Simple mode".

Bookmarks can also be associated with a series of images. To create a bookmark that spans a range of images, advance the viewer to the image for which you want the bookmark to start. Click the "Start Bookmark" button (located under the playback controls). Then advance the viewer to the image where you want the bookmark to end. Click the "End Bookmark" button. A new window titled "Create a bookmark" will appear showing you a preview of the images you selected to be bookmarked. If you selected to bookmark more than 12 consecutive images, this window will select 12 representative images from the range and display them. The image in the top left corner is always the first image in the range you selected. The image in the bottom right corner is always the last image in the range you selected. You can type in the text field the bookmark text. Press the "Make Bookmark" button. The "Create a bookmark" window will close, and the bookmark will be added to the range of images. The bookmark will show up in the bookmark list in the left hand side and the bookmark text will be overlaid on the image accordingly.The list of bookmarks can be

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sorted by bookmark name, or by the position of the bookmark within the image sequence (i.e. by time). Bookmarks can be permanently deleted using the 'Remove' button. The entire list of bookmarks can be temporarily hidden with the 'Hide Bookmarks' button at the top left of the display.

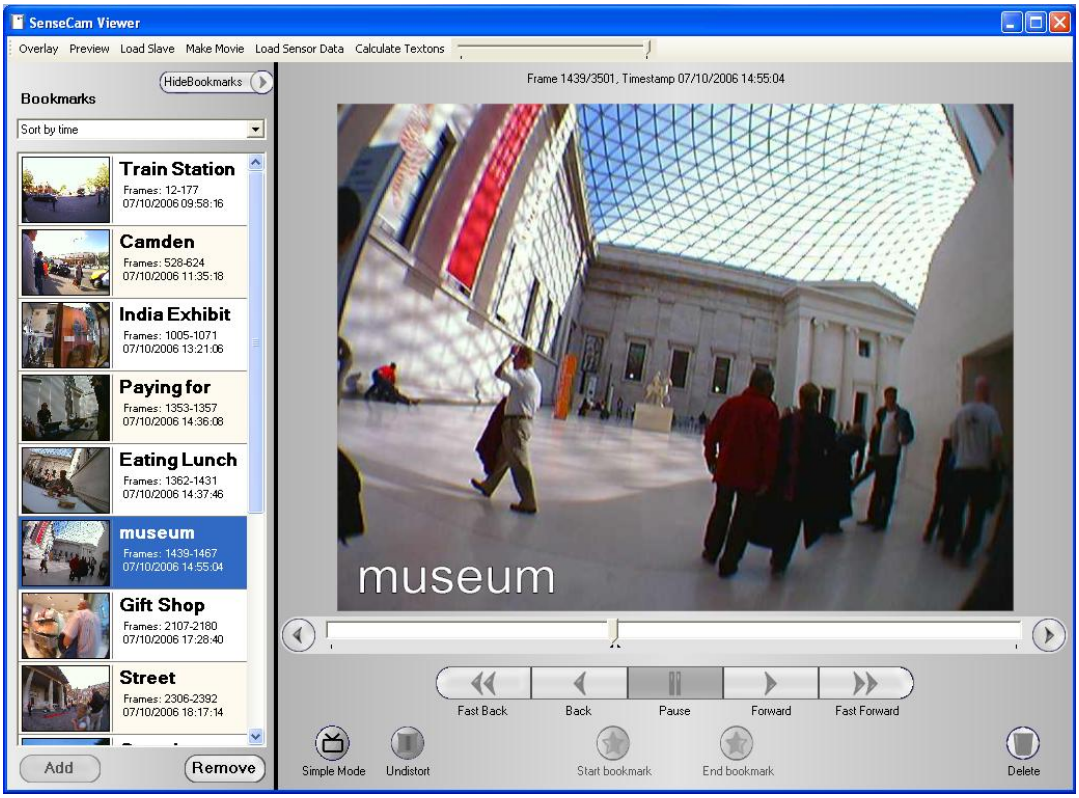

Figure 7: Bookmarks are shown as overlay text on the image.

3.4. 'Advanced' operation of the SenseCam Image Viewer

If the SenseCam Image Viewer software is installed with 'Advanced Operation' selected, then there will be several additional options available at the top of the window. These options are not available in the Basic installation.

Overlay: Displays an analogue clock face to the right of the image sequence indicating at what time of day the image displayed was originally taken. The hands on the clock face spin around as the movie is played. To enable the analogue display overlay, single click on the option. To remove the display, click on the option again.

Preview: Opens the Windows picture preview window on the current image, thereby providing access to printing and editing. Changing the currently selected image while the preview window is still displayed is not recommended.

Load Slave: Allows additional SenseCam image sequences to be loaded in and displayed at the same time as the main sequence. This is useful if you have sequences that were recorded at the same time – for example if two or more people were wearing SenseCams at an event. For each additional image sequence that is loaded in, a new viewing window is created. Playback will result in the individual image sequences playing in their respective windows in synchronisation with each other. This is also useful for playing back sequences where

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more than one camera was worn by one person (e.g. one facing forwards and one facing back.)

Make Movie: This is a prototype feature to convert a SenseCam image sequence into a self-contained movie file. To use this option you first need to install Windows Media Encoder (WME). This is used to perform the final encode to .WMV step and, if it's not installed the viewer software currently generates an "object not found" error message and aborts. WME can be downloaded from http://www.microsoft.com/windows/windowsmedia/forpros/encoder/default.mspx. "Windows Media Encoder 9 Series" is the only version used in testing. Before clicking the Make Movie button, choose the image run you want to make into a movie – the dialog box allows you to specify start and end frames by number, but doesn't currently allow you to preview them while the dialog box is open. Section 3.6 gives more details on Make Movie options.

Load Sensor Data: Loads in the sensor data associated with the image sequence and plots each type of data as a graph with the timeline over which all the images were captured along the x axis. The raw sensor data values are plotted, with a black vertical line at the time corresponding to the picture displayed in the main window. This display is very rudimentary and not particularly efficient, but does provide a quick visualisation of the sensor data. The 'CAM' plot shows the reason for each photo capture, where 1 = timer, 2 = PIR, 4 = light level, 8 = manual capture. The 'RST' line (not shown in Figure 8) shows pulses where the camera is turned on or off. Double-clicking on the window brings up a dialog box that allows each of the values to be selected (i.e. shown on the graph) or deselected (i.e. hidden). By default they are all shown, including the texton parameters Chi Sq, Squared and Alpha D (see below). There is a zoom function which can be used when a lot of sensor data readings are displayed, this is activated by using the scroll wheel on a suitably-equipped mouse. When the sensor data is displayed, the speed of the "fast forward" and "fast back" image display options will be degraded due to the sensor data redraw times.

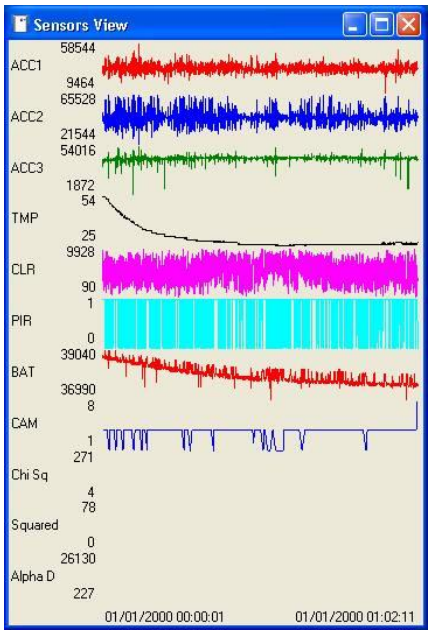

Figure 8: Sensor data display

You can supply additional sensor data lines, either by editing the SENSOR.CSV file, or by creating a new .CSV file in the same format (see later) – you can use any tag you like, and it will be presented as a separate trace on the graph. This file should be time ordered, as SENSOR.CSV is, and *must* have a correctly formed real-time clock line before any of the new data, and at least on every midnight transition (in order to correctly specify the date).

Calculate Textons: Processes the entire sequence of images to determine which images are most like each other. This option typically takes a while to run – for example it will likely take a couple of minutes on a 3GHz processor with 100 images to process. There is currently no progress bar during this operation – the UI will simply appear to hang until it has completed – so once it's started, it's just a case of waiting until it's complete… The

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image similarity data that is generated is cached (in the image.dat file) so that it is available subsequently without requiring re-generation. When textons have been generated, a number of marks appear under the image playback progress bar – these indicate points in the image sequence where the scene appears to change significantly – and they therefore effectively split the image sequence into segments of related images. The sensitivity of this segmentation is adjustable using the slider to the right of the 'Calculate Textons' option.

3.5. Sequence of operations when the SenseCam Image Importer runs

The Image Importer performs the following sequence of actions:

1. Saves a copy of the current PC time for later use (step 6 below).
2. Creates a new directory on the PC into which to store everything from the SenseCam.
3. Iterates over every file on the SenseCam in any directory under \DATA:
    a. Copies JPG files to the PC. Images may be rotated if necessary. EXIF timestamps and TIFF manufacturer ("Microsoft") and model ("SenseCam") headers are added as files are copied across
    b. Copies the one and only log (SENSOR.CSV) file to the PC
4. Deletes everything under \DATA and including the DATA directory itself. (This is *extremely* time consuming despite the USB 2.0 connection. This is not due to any aspect of SenseCam firmware, but is because of the nature of the FAT file system on flash memory devices.)
5. Deletes any existing \SYSTEM\TIME.* and writes a new \SYSTEM\TIME.CSV with the time recorded in step 1 above. In this way, TIME.CSV will contain the time at which the SenseCam was connected to the PC (to a reasonable approximation).
6. Finally, invokes the viewer (or other application) on the copied directory.

3.6. SenseCam Viewer configuration file

Several aspects of the SenseCam Viewer operation may be controlled by altering the XML format configuration file in the install directory (by default <program files>\Microsoft Research Ltd\SenseCam). Do be careful when editing this file: if the viewer application cannot read it, it will not start. Note that the file is only read when the program starts, so changing it while the viewer is running will have no effect until you restart.

Viewer.SlowInterval/Viewer.FastInterval:

There is some limited playback speed control via the two lines:

```
<add key="Viewer.SlowInterval" value="500" />
```

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<add key="Viewer.FastInterval" value="40" />

These give the target time delay between images in milliseconds for "slow" and "fast" forward/backward buttons. Note that the fastest speed will be whatever your PC can manage, so it can max out before getting down to your chosen speed.

Viewer.Toolstrip.Visible:

The advanced options are displayed in the viewer if the Viewer.Toolstrip.Visible key is set to True:

<add key="Viewer. Toolstrip.Visible " value="True" />

When set to False, the basic mode of the viewer will be in operation.

Viewer.Left.Visible:

Viewer.Left.Visible shows or hides the Bookmark window on program startup.

Viewer.KeepAvi:

The 'Make Movie' option mentioned in Section 3.4 above first assembles the chosen run of images into a large uncompressed .AVI file, then runs WME to convert that into a much smaller .WMV file, deleting the .AVI file after. WME is typically used with a "profile" – a set of encoder parameters such as bit rate and image size: a few SenseCam specific profiles are provided (the ones starting with "SC"), but they have not been tuned at all. To allow experimentation with other parameters (and creation of better profiles), you can disable the deletion of the .AVI file by setting Viewer.KeepAvi to "True" and then run WME directly on that (to be found in your TEMP directory, with a name like "tmpABCD.tmp.avi"). The WME installation pack includes a tool to create profiles, which you can then copy into the Profiles subdirectory and have appear in the make movie dialog box. (If you call them "SC something" they'll appear in the same place in the list as the existing ones, making them easier to locate.) If you use WME directly, you can also add additional channels – such as audio. You could also use Windows Movie Maker on the .AVI file to glue together several segments and add various transition effects.

Figure 9: MSRC SenseCam Image Viewer configuration file options.

3.7. SenseCam Viewer registry settings

As well as the configuration file described above, some settings are specified via the registry (typically ones that affect more than just the viewer).

The application that is invoked by the SenseCam Image Importer can be changed by specifying an executable in **HKEY_CURRENT_USER\Software\Microsoft Research Ltd\SenseCam\Viewer**, ideally using the full path (although that is not necessary in some

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cases). The executable is passed the destination directory as a command line argument. As an example, if you specify "explorer.exe" in that registry key, Windows Explorer will be opened on the target directory via the command line "explorer.exe "<full path to copied directory>"". If the registry entry is omitted, the default is the MSRC viewer.

The registry key **HKEY_CURRENT_USER\Software\Microsoft Research Ltd\SenseCam\ImageRoot** is used to specify the location where SenseCam data is imported to, and where the SenseCam Image Viewer expects to find image sequences. By default it is set to "C:\Documents and Settings\<username>\Local Settings\Application Data".

The SenseCam hardware produces upside-down (i.e. 180° rotated) images natively. The latest SenseCam firmware can be configured to rotate all images by 180° inside the camera, so that they appear right-side-up. By default, the SenseCam Image Importer will check the SenseCam configuration (recorded in the SENSOR.CSV file) and will rotate images during import if necessary (i.e. if this was not done by the SenseCam firmware). This behaviour of the Image Importer can be manually overridden (i.e. the importer will always rotate the images) by creating registry DWORD ImageRotate in HKEY_CURRENT_USER\Software\Microsoft Research Ltd\SenseCam. Setting **HKEY_CURRENT_USER\Software\Microsoft Research Ltd\SenseCam\ ImageRotate** to 0 means no rotation, 1 means importer should rotate.

3.8. SenseCamFileCopier

One of the files in the install directory of the SenseCam Image Viewer (C:\Program Files\Microsoft Research Ltd\SenseCam Import by default) is SenseCamFileCopier.exe. This executable is responsible for the file import process described in Section 3.2. During the course of data import to the PC, SenseCamFileCopier.exe is run from within the root directory of the SenseCam (e.g., E:\).

SenseCamFileCopier.exe can also be used manually to (re-)import a previously backed up SenseCam file system into the standard viewing location. For example, if a SenseCam file system has been copied to C:\SC_Backup (in which case C:\SC_Backup will contain \DATA and \SYSTEM directories), then the data in C:\SC_Backup may be imported manually by opening a DOS command prompt in C:\SC_Backup and running SenseCamImageCopier.exe from that location.

Note that the executable takes a single optional command line argument, /autoplay – if this is set (as will be the case for a normal, automatic SenseCam import), the files on the source will be deleted; if not, the source is untouched.

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4. SenseCam operation in more detail

4.1. SenseCam configuration

Various aspects of SenseCam operation are configurable at the time of camera production.[2] These configuration options are stored in non-volatile EEPROM memory in the SenseCam microcontroller. Section 5.4 describes how the BOOT.BAT file may be used to override and/or change the different configuration options.

4.2. Sensor-based image capture algorithm

The SenseCam runs a very simple algorithm that determines when a new image should be captured, based on some of the sensor values and the passage of time. The basic algorithm is listed in Figure 10. Note that each of the individual capture triggers can be overridden using the BOOT.BAT file (see Section 5.4). The parameter of `TakePicture()` is logged as the reason code in the SENSOR.CSV file.

```
while (true)
{
       if (do not disturb mode) continue;
       if (continuous triggering enabled)
              TakePicture('C');

       if (manual triggering enabled)
              if (manual shutter button pressed)
                     TakePicture('M');

       if (sensor triggering enabled)
       {
              if (significant change in white light level)
                     if (not taking a manual picture anyway)
                           TakePicture('L');

              if (SenseCam is stationary && PIR has changed state)
                     if (not taking a manual picture anyway)
                           TakePicture('P');
       }

       if (timer triggering enabled)
              if (timed out)
                     if (not taking a manual picture anyway)
                           TakePicture('T');
}
```

Figure 10: Basic SenseCam image capture algorithm.

[2] Technically these are actually set at the time that the camera is commissioned at MSRC, rather than at time of assembly of the electronics.

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4.3. Interpreting the lights on the SenseCam

There are three lights (LEDs) on the top of the SenseCam that can be used to determine the status of the device (see Figure 11). The green 'power' LED is used to indicate whether the unit is switched on or not (illuminated or not respectively). Furthermore, if this LED is blinking intermittently, this means that the battery is running low and should be recharged.

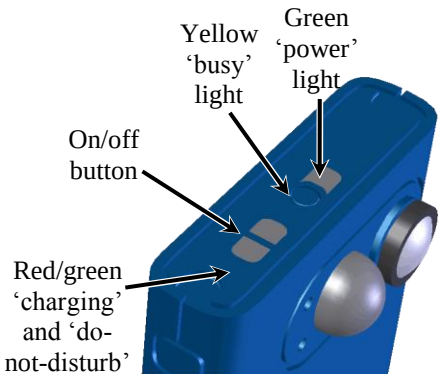

Figure 11: SenseCam LEDs.

The yellow 'busy' LED is used to indicate that the SenseCam microcontroller is busy. This is typically when the unit is reading sensor information and storing it into flash memory, but may also indicate some other kind of internal operation. For example, whenever the SenseCam is powered on it has to spend a few seconds initialising and during this time the yellow LED is illuminated.

The red/green 'charging' and 'do-not-disturb' LED has two functions. Normally (when do-not-disturb mode is not active), it will illuminate when a charger or PC has been connected to the SenseCam via the USB connector. It flashes green when the SenseCam is charging, and changes to a constant green LED when charging is complete. In addition, it will flash red whenever there is a USB data transfer, which typically occurs during docking with a PC and downloading of SenseCam images and data.

When 'do-not-disturb' mode is activated (using the topmost of the side buttons), the red LED will be lit to indicate that do-not-disturb mode is active and no pictures will be taken. This lasts for around 7 minutes. When there are 15 seconds left in do-not-disturb mode, a tone will be played and the red LED will continue flashing until either the time runs out (and pictures restart), or the do-not-disturb button is pressed again (causing the LED to go solid red again, and the timer to restart).

The red LED should never illuminate when the SenseCam is connected to a USB charger unit as there should be no data exchange.

Finally, all three lights will flash briefly on completion of the power up sequence.

Green 'power' LED	
LED status	Meaning
Off	Switched off
Solid green	Switched on and operating with good battery capacity
Intermittently blinking green	Powered up and operating with

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poor battery capacity

Figure 12: Summary of the meaning of the green 'power' and red/green 'charging' LEDs.

Red/green 'charging' and 'do not disturb' LED	
LED status	Meaning
Off	No charger or PC connected, do-not-disturb mode off
Solid green	Either a charger or a PC is connected via USB & battery is fully charged
Blinking green	Either a charger or a PC is connected via USB & battery is being charged
Intermittent red	A PC is connected via USB, and data is currently being exchanged between the PC and the SenseCam
Solid red	Do-not-disturb mode active
Blinking red	Do-not-disturb mode ending shortly

4.4. Interpreting the sounds from the SenseCam

There are five main audio cues utilised by a SenseCam to indicate specific actions either underway or completed:

Rising cadence: The SenseCam is switching on and will soon be ready for operation. It is normally followed by a final "beep" when the unit is fully operational.

Falling cadence: The SenseCam is switching off.

Beep: A manually triggered photo is being taken; it is sounded at the exact time that the image is taken. A similar beep also occurs when the camera is first ready for use after it has been switched on; in this case there is no associated photo capture.

Low warble: The battery level in the SenseCam is insufficient for the unit to switch on; the battery must be charged before the unit can be switched on.

2-tone low-high beep: Do-not-disturb mode will end shortly

4.5. Lens

The lens fitted to the SenseCam is a V-4301.9-2.0FT-IRC from Marshall Electronics. This is a 119º (diagonal) wide-angle lens with an IR filter in an M12x0.5mm form factor. In theory this can be replaced by a different specification M12x0.5mm lens. To do this:

1. Loosen the small set (grub) screw which locks it in place using a suitably-sized allen key (0.9mm between flats).
2. Remove the existing lens by carefully unscrewing it. Be careful not to let the image sensor get dirty while it is exposed.
3. Fit the replacement lens, being careful not to cross-thread it (this would permanently damage the plastic thread in the SenseCam case) and being careful not to screw it in so far that it touches the image sensor (this would permanently damage the image sensor).
4. Manually focus the lens by iteratively taking pictures with the SenseCam, viewing them on the PC and adjusting how far the lens is screwed in.

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5. Tighten the lens using the set screw and allen key. Take care not to over-tighten; this might result in permanent damage to the camera.

Steps 2, 5 and 6 above may also be used to fine-tune the focus of the SenseCam with the lens as supplied. It is suggested that the unit be focussed using a visual target of high contrast at a distance of between 1 and 2 metres from the camera for general-purpose use. Special applications may require the camera to be focussed closer to or further from the camera.

4.6. Internal flash memory

All the sensor and image data is stored on an SD card inside the SenseCam. The VGA resolution images recorded by SenseCam are stored as compressed JPEG files with a typical size of around 30k bytes. This allows for over 30 thousand images to be stored on the standard 1GB SD card.

The SD card is not designed to be removed by the end user, and can only be accessed by taking the back off the SenseCam and removing the PCB assembly. This operation is not recommended, but would allow the card to be replaced if necessary. The SenseCam has only been tested with 1GB and 2GB SD cards. The new 4GB SD cards will not work.

4.7. Battery lifetime and charging

The 980mAh lithium-ion battery in the SenseCam should give around 36 hours of continuous operation, although this will depend on how frequently images are taken since the VGA camera module and SD card are quite power-hungry. Very frequent image capture may reduce battery life to around 12 hours. Turning the SenseCam 'off' by pressing the power button simply causes the SenseCam circuitry to enter a non-operational, very low power sleep mode. In this mode the real-time clock, which is needed to time-stamp images and sensor data when the camera is next switched on, is left running. The camera draws just 152uA in low power mode, so it will run for up to 9 months before the battery is completely drained.

The battery charge can be 'topped up' at any time by connecting the SenseCam to a power source (either a USB host, USB hub or the supplied USB mains charger). It is strongly recommended that you switch the SenseCam 'on' before connecting it,[3] because this is the only way to ensure that the red/green 'charging' LED correctly reflects the state of the device (see Section 4.3). The lithium-ion battery should be pretty immune to the 'memory effect' associated with other rechargeable battery chemistries, so 'topping up' should not affect the capacity of the battery.

If the battery charge becomes low during operation of the SenseCam, the green 'power' LED will flash intermittently as a warning to the user (see Section 4.3). Eventually, the charge will become so low that the SenseCam microcontroller will automatically switch the device off. Trying to switch the unit back on in this condition will result in a low pitched warble (see Section 4.4 above). Obviously in this case the SenseCam must be connected to a power source with the unit still switched 'off'. After around 15 minutes of charging, disconnect the SenseCam and switch it on (the battery should have enough charge to do

[3] Even though the SenseCam will promptly switch itself off as soon as the connection is detected.

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this), then resume charging if required (and this time the red/green 'charging' LED will be operational.

If the SenseCam is run until it powers itself off, and *then* left for several weeks without re-charging, the real-time clock may be reset to 0:00:00 on 1/1/2000. All images taken subsequently will have the correct *relative* timing (assuming a further reset to the real-time clock has not occurred). The real-time clock can be set to the correct time automatically using the MSRC SenseCam Image Importer or manually using the BOOT.BAT or TIME.CSV files (see Section 5).

With the default SenseCam configuration (fast charge enabled, see Section 4.8 below), the battery will take around 3 hours to recharge from being completely flat. The SenseCam will charge at the same rate whether connected to a USB mains adapter or a USB host or hub.

4.8. Adjusting the charge current

The maximum amount of current drawn by the SenseCam when charging can be set to one of two different values to result in a fast or slow charge time (around 3 hours or 10 hours respectively). The default operation is fast charge, which draws a current close to 500mA, the maximum permitted over USB. However, due to the hardware USB device implementation (see Section 6.1), when the SenseCam is enumerated over USB following its connection to a host/hub it will not correctly specify this requirement for 500mA. This will result in the SenseCam drawing more current than the USB host/hub expects, which *may* in turn result in errors on the USB bus. This is very unlikely when connecting the SenseCam directly to a host (i.e. in the back of a desktop or laptop computer) or when connected to a *powered* USB hub. If problems are experienced when using a powered hub, it is possible to configure the SenseCam to operate only in slow charge mode, which draws significantly less current. This can be done using the 'fast' BOOT.BAT command or by altering the configuration bits (see Sections 5.4 and 5.7 respectively).

4.9. Complete power off with concealed switch

The on/off button powers down nearly all of the circuitry in the SenseCam, but it does keep the real-time clock running (so that the camera doesn't lose track of time) and it maintains the processor in a very low-power state.

If there is a special reason to switch off the SenseCam completely then it is possible to use a small concealed 'hard' on/off switch which disconnects the battery and therefore causes a complete power off. This switch is hidden behind one of the two buzzer 'grille' slots and must be operated using a paper-clip (or similar). To switch the SenseCam off, insert the end of a paperclip into the top of slot that is nearest the front of the SenseCam and slide it down. Similarly, to switch the camera back on insert the paperclip at the bottom of the slot and slide it up. You should not need to insert the paperclip more than 10mm, and if you feel resistance make sure that you are inserting the paperclip *right at the end* of correct slot.

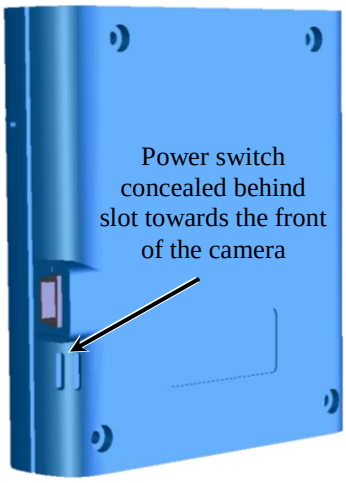

Figure 13: Hidden power switch

If the SenseCam is hard power-cycled then the RTC will be reset to 0:00:00 on 1/1/2000.

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If for some reason the camera appears to have stopped working at any time, as a last resort it may be necessary to switch the power off completely as described above, wait ten seconds, and then power it back on again. Ideally, the slide switch should only be used after the camera has been put into the 'off' mode with the power button, to make sure that all files are flushed to memory cleanly.

4.10. Slow start-up

The SenseCam can sometimes be slow to boot up when switched on. One reason for this is the time required to reopen a very large SENSOR.CSV file in order to append to it – this requires traversal of a large number of cluster chains. The best way to mitigate this is to synchronise the SenseCam with the PC reasonably frequently, thereby moving all the files (including the SENSOR.CSV file) off the device. If this is not possible, the only alternative is to wait (perhaps many minutes).

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5. SenseCam file formats

5.1. Volume label

The SenseCam volume label will be of the form "MSRC_SC xxx" where xxx is the serial number of the particular camera. If the volume label is changed manually it will be reset when the SenseCam next boots up (following a hard power cycle or a USB disconnect), unless the volume label is deleted (in which case no new volume label will be created).

5.2. File system structure

The root directory on the SenseCam file system typically contains four sub-directories: DATA, SYSTEM, PCVIEWER and DOCS. The latter two folders are simply used as convenient places to store copies of the MSRC viewer software and SenseCam documentation. Their presence (or absence) has no bearing on the operation of the SenseCam. Indeed, it is possible to use the SenseCam as a general-purpose external USB disk. Note that the SenseCam firmware does not support long filenames.

The SYSTEM directory contains system files, most notably BOOT.BAT – a script file that is executed *each time* the SenseCam boots up (following a hard power cycle or a USB disconnect). The various BOOT.BAT options are detailed below in Section 5.4. The SYSTEM directory also contains various .CSV format files that may be used to set the real-time clock on the SenseCam. These are also detailed below.

The DATA directory contains all the image and sensor data recorded by the SenseCam. Sensor data is recorded in a single .CSV file called SENSOR.CSV, described fully in Section 5.5. An image counter internal to the SenseCam (which is cached in non-volatile memory) records how many images have been captured in the lifetime of the device. Images are stored as individual .JPG files with a numeric filename based on the value of the image counter. These image files are stored within a hierarchy of directories. For example, image number 00010297.JPG is stored in a directory named 'M0102' which itself is in a directory named 'H01' within the \DATA directory. This multi-level structure, with High level directories named according to the most significant two digits of the six-digit image counter and Medium level directories named according to the most significant four digits of the six-digit image counter limits the number of entries in each directory to around 100. This is important because it reduces the time required for creating and accessing files – with the limited resources of the SenseCam microcontroller the linear search through a directory cluster chain can be quite time consuming.

If a manual capture is requested (via the manual shutter button) whilst a sensor-triggered image capture is already in progress, the image file currently being written is aborted, the image counter is incremented and a new image file is created. In order to prevent the aborted image from being mistaken for a valid .JPG file (it will actually be the first part of an incomplete .JPG file) it is renamed with the extension .ABO (for ABOrted).

5.3. Format of the SENSOR.CSV file

The sensor data is stored in a simple comma separated value (.CSV) file, where every line represents one piece of sensor (or other) data. Lines are <CR><LF> separated. Every line entry starts with a 3-letter code indicating what that line represents. If the SENSOR.CSV file does not exist (for example if it has been deleted following sensor data import using the SenseCam Image Importer) it will be recreated. If it does exist it will be appended to.

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With sensor readings, the 3-letter sensor code is followed by the time that the reading was taken in hours (24 hour clock), minutes and seconds, and then followed by the value of the reading. Since each sensor entry only logs the time of the reading, we periodically (every hour in the latest firmware) log the time *and date*. In addition to environmental sensing, we also periodically check and log the internal battery terminal voltage. Whenever an image is captured, the time of capture and the filename used to store the image are recorded in the log file, along with a one-character 'reason' code (why the SenseCam took a photo at that time). When the camera boots up from cold, or is USB sync'ed or unsync'ed , it adds three entries to the sensor log file which indicate the time, date and build directory for the firmware, the version of the firmware, and various bits of system information.

Temperature data is represented by a 9-bit, two's complement word with an LSB (least significant bit) equal to 0.5°C. For positive temperature readings simply divide by two to convert to centigrade. The table in Figure 14 opposite gives some example conversions.

Temperature	Binary	Hex
+125°C	0 1111 1010	0FAh
+25°C	0 0011 0010	032h
+0.5°C	0 0000 0001	001h
0°C	0 0000 0000	000h
−0.5°C	1 1111 1111	1FFh
−25°C	1 1100 1110	1CEh
−55°C	1 1001 0010	192h

Figure 14: Example temperature readings and the corresponding SENSOR.CSV values.

```
VER,2,6,6
FIL,C:\Development\SenseCam\firmware\PIC\main_v22.c,10:52:21,16-May-06
SYS,00000167,0x00,0x03,0x1f,0xff
RTC,2006,06,19,12,28,02
ACC,12,28,07,00034,00848,00036
TMP,12,28,07,00047
CLR,12,28,07,03756
PIR,12,28,07,1
BAT,12,28,07,41821
CAM,12,28,11,00000230.JPG,M
...
```

Figure 15: Example SENSOR.CSV file entries.

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	Sensor/meaning	Interpretation
ACC	Accelerometer	Raw x, y and z acceleration values in 1/819ths of a g with a constant 2048 offset
CLR	Colour light sensor	The sensed value for 'white' light
PIR	Passive infrared detector	Whether the sensor is currently triggered or not (1 = triggered, 0 = not)
TMP	Temperature sensor	Temperature in ½ degrees Celsius (stored as two's complement, see below)
BAT	Battery	Battery terminal voltage in hundreds of microvolts.
CAM	Image capture	Image filename, reason (P = PIR activated, T= timer, M = manual capture, L=light-level change)
RTC	Real-time clock	Year, month, day, hour, minute, second.
FIL	Filename	Directory path to the 'main.c' file of the build, time of build (hh:mm:ss) and date of build (dd-Mmm-yy).
VER	Version of firmware	Major, middle, minor
SYS	System information	Camera serial number, brown-out count, watchdog timeout count, config0 and config1 bits setting. The serial number is actually recorded as hex, but our numbering convention is to use BCD so it actually reads out as if it were decimal.

Figure 16: Keywords used in the SENSOR.CSV file and their meanings.

5.4. BOOT.BAT system file

There is an optional file called BOOT.BAT on the SenseCam flash drive in the \SYSTEM folder. BOOT.BAT lists a sequence of commands that will be executed every time the SenseCam boots up, i.e. following a hard power-cycle using the hidden slide switch or following USB disconnection (from a PC or battery charger). The commands that may be included in BOOT.BAT are listed below. Note that the BOOT.BAT file is optional; if it is not present or if it contains no commands, then the SenseCam will just exhibit the default behaviours.

fast

Summary:	Turn fast charging on or off
Syntax:	fast 'y'|'n'
Description:	The fast command can be used to override the default charging behaviour (see Section 4.8). Slow charging may be needed if connecting the SenseCam causes errors on the USB bus.
Example:	fast n

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gap

Summary: Specify period for timer based snapshots
Syntax: gap <time-interval>
Description: The gap command can be used to very roughly specify interval delay between successive snapshots for timer-based image capture. <timer-interval> is the interval specified in seconds ranging from 1 second to 16000 seconds (~4½ hours). If no image has been captured for <timer-interval> seconds then an automatic snapshot will be performed.
Examples: gap 20
GAP 192
gap 2

#

Summary: comment
Syntax: # <comment-string>
Description: The # command can be used to insert comments into the BOOT.BAT file without incurring syntax errors. <comment-string> is simply a line of text which will be echoed to the debug console. The line must have the '#' character as the first character on the line and is otherwise ignored by the SenseCam command line parser.
Examples: # This is a plain old comment which will be ignored by the parser
The next command is a comment too
… just as the last line was a comment

trig

Summary: Set trigger mode
Syntax: trig <trigger-bitmask>
Description: The trig command can be used to specify the active trigger mechanisms during SenseCam operation. This can be used to enable or disable specific sensor input. The <trigger-bitmask> supplied must be the inclusive OR of one or more of the following bits:

0x0002	Sensor-based (PIR, light & accelerometer) triggers
0x0100	Manual button-based trigger
0x0200	Timer-based trigger
0x0400	PIR trigger
0x0800	Light level trigger
0x1000	Accelerometer trigger

Note: if the 'enable sensor based triggers' (0x0002) bit is not set then the PIR, light level and accelerometer sensing trigger settings are ignored and only the manual button and timer based trigger settings are used.
Important: the bitmask parameter may be specified in decimal or hexadecimal. For hexadecimal values it is important to prefix the bitmask with the '0x' string.

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Examples:	trig 0x1F02	; manual, timer-based, sense-driven camera (default)
	trig 0x0100	; manual digital capture only
	trig 0x0200	; timer-based capture only
	trig 0x0300	; manual and timer-based capture only
	trig 0x1C02	; sense-driven only (no manual/timer-based photos)
	trig 0x0402	; only run as stationary PIR monitoring camera

tim, dat

Summary:	set real-time clock time and date
Syntax:	tim <hours> <minutes> <seconds> dat <day-of-month> <month-of-year> <year>
Description:	Set the real-time clock to specific values. Note that the BOOT.BAT file will need to be modified manually after the tim or dat commands have been used to prevent the real-time clock from being set to the same values every time the SenseCam executes the BOOT.BAT file. Manual time setting is best achieved by using the TIME.CSV file (see Section 5.5 below).

eewrite

Summary:	Specify non-volatile configuration settings
Syntax:	eewrite <config-byte> <new-value>
Description:	Several non-volatile configuration bytes which control various aspects of SenseCam operation are stored in the on-chip microcontroller EEPROM. These may be overwritten using the eewrite command by specifying the <config-byte> number and the <new-value> to store at that location. Since this configuration information is stored in non-volatile memory, having set the desired values, the eewrite commands in the BOOT.BAT file may be deleted. Most of the configuration bytes should not be altered by the end user. Altering their contents may cause problems operating the SenseCam and in the worst case ***will render it inoperable***. Do not use this command unless you are confident that you understand what effect it will have! See 5.7 below for more detail on useful settings.

Examples:	eewrite 8	;
	eewrite 9 0x02	; no power saving

Figure 17: BOOT.BAT commands.

5.5. TIME.CSV system file

The TIME.CSV file in the \SYSTEM directory is used to update the real-time clock on the SenseCam. On boot up (following a USB disconnect and a power-on) the SenseCam will use the information in the TIME.CSV file to set the real-time clock, and will then delete the TIME.CSV file. See Section 3.5 for more details on this process.

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The TIME.CSV file can contain up to two lines, one for setting the time of day and the other for setting the date. The format for these two lines is the same as the tim and dat BOOT.BAT commands (either spaces or commas can be used as parameter delimiters).

5.6. SenseCam action on connection to and disconnection from USB

When the SenseCam detects a USB connection, it stores the current real-time clock value in its internal non-volatile memory. It then shuts down the file system and peripherals, makes the SD card available to the USB device controller, and enters its low-power sleep mode.

On disconnection from USB, SenseCam looks for the file TIME.CSV in the \SYSTEM directory. If it exists, the time difference between the time stored in TIME.CSV and the time stored internally is calculated and then added to the (continually advancing) SenseCam real-time clock. This mechanism ensures that SenseCam time is set to the time of the PC, no matter how long the camera was docked for. After setting the real-time clock in this way, the SenseCam then deletes TIME.CSV.

Having altered the real-time clock if appropriate, the SenseCam will continue to boot up. During this process it will retrieve the configuration settings from non-volatile memory, and finally it will read and act on the BOOT.BAT file in the \SYSTEM directory (see below for details). It is possible that BOOT.BAT file commands will override defaults set in the non-volatile memory.

5.7. Non-volatile configuration options

There are two configuration bytes in the non-volatile memory of the SenseCam that may be changed by means of the eewrite command in the BOOT.BAT file. The current values of these configuration bytes are recorded in the SYS entry in the SENSOR.CSV file.

Modifying factory-shipped configuration options is not recommended since it may adversely affect the operation of the SenseCam, and if the commands are entered in error it may render the SenseCam inoperable.

If the config0 and config1 bit settings described in the tables below are to be modified after the camera has been shipped, it is recommended that all bit settings in positions which are not explicitly described below should be preserved from the values in the default original SENSOR.CSV records. This will avoid inadvertently changing other internal (potentially critical) functionality.

The address and bit meanings of these two configuration bytes are as follows:

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config0 byte [eewrite address 8]									
	0	*0*	*0*	*1*	*1*	*1*	*1*	*1*	*default factory-programmed value: 0x1F*
Control	**b7**	**b6**	**b5**	**b4**	**b3**	**b2**	**b1**	**b0**	**Description**
Fast charge *bitmask 0x01*								0	Turn off fast charging.
								1	Turn on fast charging. See Section 4.8 for more details on this. Use the ***fast*** command in BOOT.BAT in preference. This is the default setting.
Push-button mapping *bitmask 0x04*						0			Button map A. Manual snapshot button is mapped to the top of the SenseCam. Power/standby mapped to top side button of SenseCam. Use this if you are keen to have the shutter button on the top of the camera.
						1			Button map B. Manual snapshot is mapped to the bottom side button of SenseCam. Power/standby button is mapped to the top of SenseCam. This is the default setting.
Image inversion *bitmask 0x08*					0				Turn off image inversion correction.
					1				Turn on image inversion correction. This is the default setting. Natively the images produced by the SenseCam are up-side down. More recent builds of the SenseCam firmware can correct for this by commanding the built-in camera module to produce images right-side-up. If this option is not selected, images will appear up-side down until imported by the MSRC SenseCam Image Importer.
Double snap *bitmask 0x10*				0					Turn off double-snap option. Captures images marginally faster but with less accurate exposure setting.
				1					Turn on double-snap option. This default setting captures two images back-to-back – the first image will be used by the built-in camera module to set up the exposure for the following image. Saving an image to flash memory takes much more time than capturing it, so this double-snapping doesn't have much adverse effect on performance.
Auto battery save *bitmask 0x20*			**0**						Turn on automatic battery save feature. The SenseCam will automatically go into low power standby mode if the battery voltage is below a critical threshold. This has the effect of preserving the time and date settings of the SenseCam until such a time as it is fully recharged and ready to use again. This is the default setting.
			1						Turn off the automatic battery save feature. If this option is used the SenseCam will attempt to continue running until the battery is exhausted – potentially with unpredictable results (various peripherals and storage of data in the SenseCam may stop operating correctly at different points in time). In particular, the real-time clock is likely to lose the time and date settings and some image degradation/file corruption is likely to be seen towards the end of logged data.
	b7	**b6**	**b5**	**b4**	**b3**	**b2**	**b1**	**b0**	

Figure 18: SenseCam config0 byte (address 8) bit fields and their meanings.

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Config1 byte [eewrite address 9]									
	1	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*default factory-programmed value: 0xFF*
Control	**b7**	**b6**	**b5**	**b4**	**b3**	**b2**	**b1**	**b0**	**Description**
Camera power saving bitmask 0x01								0	Turn off camera power saving. The internal camera sensor is not turned off after each image capture. This *may* be marginally faster.
								1	Turn on camera power saving. The internal camera sensor is turned off after each image capture to conserve battery power. This is the default setting.
Camera reinitialisation							0		Turn off camera re-initialisation. Prevents re-initialisation of the internal camera sensor prior to each and every image capture. This *may* be marginally faster.
bitmask 0x02							**1**		Turn on camera re-initialisation. The internal camera sensor is re-initialised prior to each and every image capture. This is particularly required if the sensor has been powered down due to camera saving (see above). This is the default setting.
	b7	**b6**	**b5**	**b4**	**b3**	**b2**	**b1**	**b0**	

Figure 19: SenseCam config1 byte (address 9) bit fields and their meanings.

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6. SenseCam hardware details

6.1. Hardware components

The SenseCam is built around a PIC 18F8722 6 MIPS microcontroller with 128KB of flash memory, 4KB RAM, copious general purpose I/O (GPIO) lines and several on-chip peripherals including PWM, UART, I^2C and SPI.

Figure 20 lists the major components in addition to the PIC along with their basic specifications and method of interface. USB connectivity is achieved using a non-standard approach – the SD card is actually multiplexed between the PIC microcontroller (which is selected when the SenseCam is recording data) and an off-the-shelf USB-to-SD card interface chip (which is selected when a USB connection is detected). This allows us to support high speed USB 2.0 operation, which allows data to be transferred at approximately 4MB/s (around 175 images per second, or 10,000 per minute). Figure 21 shows the basic architecture of the SenseCam. Figure 22 depicts the front and the back of the SenseCam PCB, highlighting the main hardware components.

Component	Part number	Specification	Interface
Flash memory	Standard SD card	To 2GB (1GB standard)	SPI
Camera module	CoMedia C328-7640	VGA (onboard JPEG compression)	UART
Camera lens	Marshall Electronics V-4301.9-2.0FT-IRC	119º (diag) wide-angle lens w/ IR filter	n/a
Accelerometer	Kionix KXP84	Tri-axis	I^2C
Temperature	Nat Semi LM75	Range -55 to +125ºC, ±2ºC	I^2C
Real-time clock	Maxim/Dallas DS1340		I^2C
Light level	TAOS TCS230	RGB intensity	PWM
Passive IR (PIR)	Seiko SKP-MS401	Miniature form factor	GPIO
Push buttons	Omron B3F-3150		GPIO
Sounder	Murata PKLCS1212		PWM
Audio recording[4]	Oki MS87V1021	2Mb DRAM for 60s audio at 8ksps	SPI
GPS[5]	n/a	External GPS unit	BT

Figure 20: The main peripherals (including all sensors) in the v2.3 SenseCam, with a summary of their specification and the method of interface to the PIC microcontroller.

[4] Audio recording is still under development.
[5] GPS information from a standalone Bluetooth GPS receiver can be logged by the SenseCam using the Bluetooth plug-in unit.

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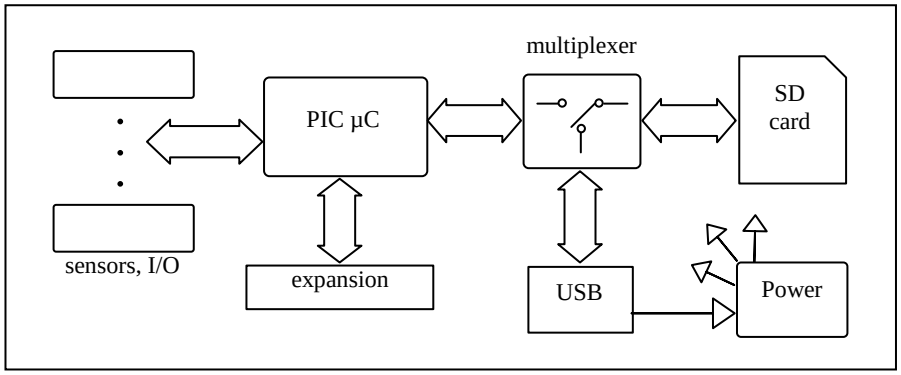

Figure 21: The basic architecture of the SenseCam. A PIC microcontroller (6 MIPS, 128kB flash and 4kB RAM) interfaces with the major components. A digital multliplexer allows the SD card to be accessed by the PIC.

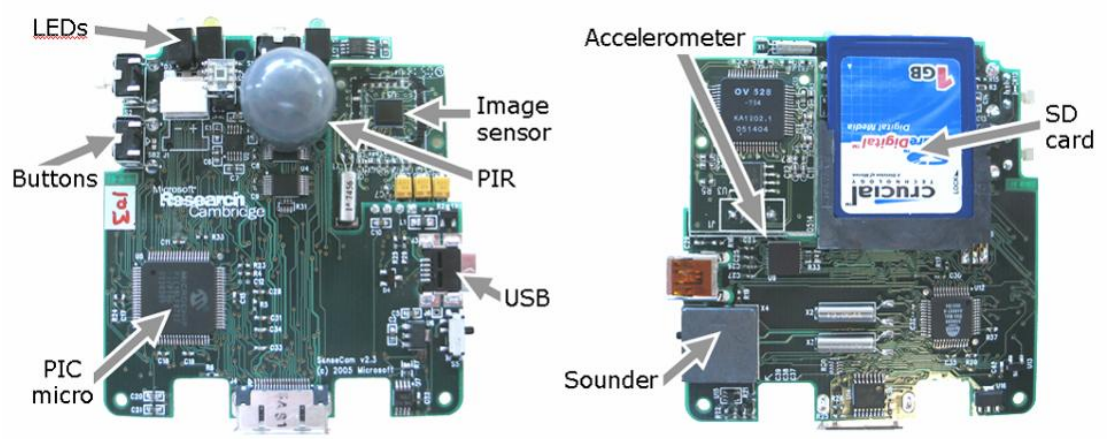

Figure 22: The front and back of the SenseCam PCB (left and right respectively).

6.2. Expansion connector

The SenseCam has a proprietary expansion port which exposes various electrical signals on the bottom of the unit. This allows extra hardware components such as additional sensors and wireless communications interfaces to be retro-fitted to the SenseCam. It also allows the SenseCam firmware to be updated and facilitates both on-chip and command line debugging. Using signals exposed via the expansion connector requires detailed knowledge of the SenseCam hardware coupled with customised firmware and is therefore beyond the scope of this document.[6]

[6] At the time of writing, Microsoft has not shared this information with any 3rd parties.

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6.3. More information

More information about the design rationales behind the SenseCam is given in "SenseCam: A Retrospective Memory Aid", Steve Hodges, Lyndsay Williams, Emma Berry, Shahram Izadi, James Srinivasan, Alex Butler, Gavin Smyth, Narinder Kapur and Ken Wood, in P. Dourish and A. Friday (Eds.): UbiComp 2006, LNCS 4206, pp. 177 – 193, 2006. © Springer-Verlag Berlin Heidelberg 2006. A copy of this paper is available on request.